Thermal Conductivity In-class Presentation - AER373 Solid Mechanics

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March 30th, 2015

Thermal Conductivity

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Introductio

Definition

Definition

Dimensionles

Dimensionles Number

Factors that influence

Thermal Conductivity

Thermal Conductivity

Table

Application

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Thermal Conductivity

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Introduction

Definition Dimensionless Number Factors that influence Thermal Conductivity Thermal Conductivity Table

Application

Thermal Conductivity

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Definition

Introduction

Definition

Dimensionless Number

Definition

Thermal Conductivity

- ▶ **Conduction**: energy transfer from the more energetic particles of a substance to the adjacent less energetic ones as a result of interactions between particles.
- In physics, thermal conductivity is rate of heat transfer through a unit thickness of the material per unit area per unit.
- ▶ It is often denoted k or λ .
- It is a property of material to conduct heat.
- ▶ It influences heat transfer rate.

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Introductio

Definition

Definition Dimensionles

Factors that influence Thermal Conductivity

Thermal Conductiv

Table

Application

Definition

Unit Dimension

▶ Unit: In SI units, it is measured by (W/mK).

▶ Dimension: $\frac{M \cdot L}{T \cdot \Theta^3}$

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Definition

Definition

Dimension

Factors that influence

Thermal Conductivit

Thermal Conductivi
Table

Application

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- ► Heat conductivity influences heat transfer rate and the relationship is given by Fouriers Law in the following form: $\dot{q} = -k \frac{\mathrm{dT}}{\mathrm{dx}}$
- rate of heat transfer per unit surface area equals to minus heat conductivity times temperature gradient
- ▶ 1-Dimensional form
- $ightharpoonup \frac{dT}{dx}$ is temperature gradient
- lacktriangle Similar to Ficks Law for mass diffusion: $J=-D rac{{
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 m d}{
 m x}}$

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Dimensionless Number

Introduction

Dimensionless Number

Dimensionless Number

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Dimensionless Number

1. **Prandtl Number** Pr: $Pr = \frac{\mu_p}{k}$

2. Biot Number Bi: $Bi = \frac{h \cdot L_c}{k}$

3. Nusselt Number Nu: $Nu = \frac{h \cdot c_p}{k}$

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Introduction

Definition

Definition

Dimensionles Number

Factors that influence Thermal Conductivity

Thermal Conductivity
Table

Thermal Conductiv

Application

Heat Sink

Introduction

Definition

Dimensionless Number

Factors that influence Thermal Conductivity

Thermal Conductivity Table

Application

Factors that influence Thermal Conductivity Temperature

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Thermal

Conductivity

Introduction

Definition Definition

Definition

Dimensionles Number

Factors that influence Thermal Conductivity Thermal Conductivity

Table
Thermal Conductivity

Thermal Conductivity
Table

Table

Application

- Gas: $k \propto \frac{1}{T^{\frac{1}{2}}}$
- ▶ **Liquid**: $k \propto \frac{1}{T}$ except water!!! For water, $k_{water} \propto T$
- ► Alloys: k increases w.r.t T
- ▶ Pure Metals: k almost constant

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Introduction

Definition Definition

Dimensionles Number

Factors that influence Thermal Conductivity Thermal Conductivity

Thermal Conductivity

Application

- Pure crystalline substances can exhibit different thermal conductivities along different crystal axes.
- ► Sapphire, k = 35 W/(mK) along the one axis and 32 W/(mK) along another axis.
- ► In anisotropic materials, k typically varies with orientation; can be represented by a second-order tensor.
- ▶ In non-uniform materials, k varies with spatial location.

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Introduction

Definition

Definition

Dimensionles Number

Factors that influence Thermal Conductivity Thermal Conductivity

Table
Thermal Conductivity

Table Conductivity

Application

Application

Heat Sink Heat Sink

Introduction

Definition

Dimensionless Number

Factors that influence Thermal Conductivity

Thermal Conductivity Table

Application

Thermal Conductivity Table

- ▶ In general, $Diamond(2300) > Metal > CrystallineSolid(100 \sim 10) > AmorphousSolid(1) > Liquid(0.1) > gas(0.01)$
- ► More Precisely

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Introduction

Definitio

Definition

Dimensionles Number

Factors that influence Thermal Conductivity Thermal Conductivity

Table
Thermal Conductivity

Table

Application

Thermal Conductivity Table

Material	Thermal Conductivity (at room temp)
Air	0.024
Pure Aluminium	204.3
Argon	0.016
Brick	0.15
Carbon Dioxide	0.0146
Pure Copper	385
Natural Diamond	2200
Glass	0.8
Pure Gold	314
Nitrogen	0.0234
Paper	0.05
Rubber	0.16
Pure Silver	406
Steel with carbon	36
Water	0.563

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Factors that influence Thermal Conductivity Thermal Conductivity Table

Thermal Conductivity Table

Thermal Conductivity

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Introduction

Definition

Definition

Dimensionle

Number Factors that inf

Thermal Conductivity Table

Thermal Conductivity

Table

Application

Heat Sink

Heat Sink

Introduction

Definition

Dimensionless Number

Factors that influence Thermal Conductivity

Thermal Conductivity Table

Application

Heat Sink

Heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium.

Most common materials for heat sinks are aluminum alloys.

Copper is also widely used.

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Introduction

Definition

Definition Dimensionle

Number Factors that influ

Thermal Conductivity
Table

Thermal Conductivity
Table

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Application

Heat Sink

Prevent overheating of computer processor.



Figure: heat sink

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Introduction

Definition

Definitio

Dimensionle

Factors that influence
Thermal Conductivit

Table
Thermal Conductivity

Table Conductivit

Applic

Heat Sink Heat Sink

For Further Reading of Interest I

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Appendix

For Further Reading of Interest



Introduction to Thermodynamics and Heat Transfer. McGraw Hill, 2005.



Approximate Formula for the Thermal Conductivity Link:

http://scitation.aip.org/content/aip/journal/pof1/1/5/10.1063/1.172431958.